PROGRAMME, LIST OF PARTICIPANTS and

ABSTRACTS

DCAMM

16th Internal Symposium

Monday, March 13 -
Wednesday, March 15,
2017

HOTEL COMWELL
MIDDELFART

TECHNICAL UNIVERSITY OF DENMARK -
AALBORG UNIVERSITY - AARHUS UNIVERSITY -
UNIVERSITY OF SOUTHERN DENMARK

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Organizing Committee:
Gerda Helene Fogt, Erik Lund, Niels Leergaard Pedersen and Mathias Stolpe

Organization:
DCAMM

General Information:

The language of presentation is English.

PhD students early in their projects present in the poster session. The session is divided in two parts; a presentation part (2 minutes, 2 slides maximum), a display of the posters. The posters should be in vertical A0 format. Please include a picture of yourself in the poster.

Second and third year Ph.D. students are given 10 minutes for their presentation and 5 minutes for discussion.

All presenters are requested to send the electronic presentations to Erik Lund (el@m-tech.aau.dk) no later than 12.00 on Wednesday 8 March 2017, also the slides for poster session must be submitted. This is to avoid delays and technical problems between the presentations. All presentations will be available on a provided computer in the conference room. Acceptable formats are Microsoft PowerPoint files (.ppt), Adobe Portable Document files (.pdf) and multimedia files which can be viewed by Windows Media or QuickTime player.

Programme for Monday afternoon, March 13th, 2017

11:30 Arrival

12:00 - 13:00 Lunch

13:00 - 13:05 Welcome and practical information,
NIELS LEERGAARD PEDERSEN (DTU Mechanical Engineering, 5 minutes)

13:05 – 14:45 DYNAMICS I
(Chairman: Niels Aage, DTU Mechanical Engineering)

JAN BECKER HØGSBERG (DTU Mechanical Engineering, 20 minutes)
Electromechanical damping of structures

ANDERS BRANDT (SDU ITI, 20 minutes)
Test and Validation in the Age of Simulations of Dynamics

ANELA BAJRIC (DTU Mechanical Engineering, 15 minutes)
Spatial identification of viscous damping from structural vibrations to random excitation

MARTIN JUUL (AU, Department of Engineering, 15 minutes)
Application of Operational Modal Analysis algorithms for Systems Identification and Finite Element model validation

XUERONG LI (AAU MAKE, 15 minutes)
Integrated Design and Modelling of an Electro-magnets Driven Spherical Parallel Manipulator

XIAOYONG WU (guest, AAU MAKE, 15 minutes)
Performance evaluation and optimal design of a 3-PPR parallel manipulator

14:45 - 15:15 Coffee break

15:15 – 16:35 WIND, FLUID & BIOMECHANICS
(Chairman: Erik Lund, AAU MAKE)

PIA REDANZ (DNV GL, 20 minutes)
Certification of wind turbines and wind farms

ANDREAS FALKENSTRØM MIERITZ (DTU Compute, 15 minutes)
High performance computing of nonlinear modulations of carrier waves in optics and water waves

MICHAEL STYRK ANDERSEN (SDU ITI, 15 minutes)
Estimation of flutter derivatives for B/D=10 rectangular section

JONAS STOLTZE (AAU MAKE, 15 minutes)
On the biomechanical relationship between external hip, knee and ankle joint moments and the internal knee compressive forces

SIMON CHRISTENSEN (AAU MAKE, 15 minutes)
Design of an upper-body exoskeleton using musculoskeletal simulations

16:45 – 17:30 POSTER PRESENTATIONS
(Chairman: Mathias Stolpe, DTU Wind Energy)

17:30 – 19:00 POSTER SESSION

Posters (started PhD after 1 April 2016 (17))

1 SIMON HEIDE-JØRGENSEN (AU, Department of Engineering)
Crack Growth Along Heterogeneous Interface During the DCB Experiment

2 SIMON SKOVSGÅRD (AU, Department of Engineering)
Modelling of Failure in Composite Materials

3 DAN THOMSEN (AU, Department of Engineering)
Vibration suppression with input shaping

4 TAO SUN (AAU Civil Engineering)
Stochastic optimal control of a point heave wave energy converters

5 PAULIUS BUCINSKAS (AAU Civil Engineering)
Fully Coupled Model of Ground and Building Vibration

6 LASSE LEDET (AAU MAKE)
Vibro-acoustics of centrifugal pumps

7 CHRISTIAN KROGH (AAU MAKE)
Modeling of Prepregs during Automated Draping Sequences

8 JON SVENNINGGAARD (AAU MAKE)
Test fixture for double cantilever beam (DCB) specimens subjected to uneven bending moments

9 MADS HOLST AAGAARD MADSEN (DTU Wind Energy)
High Fidelity CFD-based Shape Optimisation of Wind Turbine Blades

10 SÜMER DILGEN (DTU Electrical Engineering)
Topology optimization of acoustic-structure interaction problems

11 RANDI NØHR MØLLER (DTU Mechanical Engineering)
Wind Field Simulation by Low Order ARMA Processes

12 DAVID HOFFMEYER (DTU Mechanical Engineering)
Damping of Torsional Beam Vibrations

13 JULIE LYNGGAARD (DTU Mechanical Engineering)
Modeling injector related hydraulic fracturing with focus on the Halfdan field in the North Sea

14 RASMUS GRAU ANDERSEN (DTU Mechanical Engineering)
Numerical analysis of Ductile Plate Tearing under Mixed Mode Loading

15 JOHAN FREDERIK TOFTEKÆR (DTU Mechanical Engineering)
Vibration Suppression of Plates by Optimally Placed and Calibrated Piezoelectric RL Shunt Damping

16 CETIN DILGEN (DTU Mechanical Engineering)
Transient Optimization of Acoustic-Mechanical Interaction Problems

17 HANNIBAL TOXVÆRD OVERGAARD (DTU Mechanical Engineering)
Lubricant transport across the piston ring in large two-stroke marine diesel engines

19:00 – Dinner

Programme for Tuesday morning, March 14th, 2017

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(Chairman: Casper Schousboe Andreasen, DTU Mechanical Engineering)

KASPER SANDAL (DTU Wind Energy, 15 minutes)
Conceptual optimal design of jacket structures for offshore wind turbines

JACOB OEST (AAU MAKE, 15 minutes)
Topology optimization with quasi-static fatigue constraints using an effective adjoint formulation

SAID ZEIDAN (DTU Mechanical Engineering, 15 minutes)
Topology optimization for transient heat transfer problems

JEROEN PETER GROEN (DTU Mechanical Engineering, 15 minutes)
Homogenization-based topology optimization for high-resolution manufacturable micro-structures

JOAKIM VESTER-PETERSEN (AU, Department of Engineering, 15 minutes)
Topology optimized light focusing nano particles

SEBASTIAN ARLUND NØRGAARD (DTU Mechanical Engineering, 15 minutes)
Topology optimization of heat regenerators using the lattice Boltzmann method

SUNA YAN (guest, DTU Mechanical Engineering, 15 minutes)
Topology optimization of heat conduction structures using layered materials

10:45 – 11:15 Coffee break

11:15 – 12:00 INVITED PRESENTATION
(Chairman: Niels Leergaard Pedersen, DTU Mechanical Engineering)

LARS VABBERSGAARD ANDERSEN (AAU Civil, 45 minutes)
Modelling Ground Vibration and Dynamic Soil Structure Interaction

12:00 – 13:00 Lunch

Programme for Tuesday afternoon, March 14th, 2017

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(Chairman: Henrik Myhre Jensen, AU, Department of Engineering)

LARS PILGAARD MIKKELSEN (DTU Wind Energy, 20 minutes)
Revealing fatigue damage evolution in unidirectional composites for wind turbine blades using x-ray computed tomography

EMILIO MARTINEZ-PAÑEDA (DTU Mechanical Engineering, 20 minutes)
Predictive modelling of environmentally assisted cracking - a micromechanics conquest

CHRISTIAN LOTZ FELTER (DTU Mechanical Engineering, 20 minutes)
Fracture in Plate Tearing

LASSE TIDEMANN (DTU Mechanical Engineering, 15 minutes)
Beam Element with Cyclic Plasticity Effects

JEPPE BJØRN JØRGENSEN (DTU Wind Energy, 15 minutes)
Crack deflection at interfaces

14:35 - 18:00 Social Event

19:00 - Banquet

Programme for Wednesday morning, March 15th, 2017

07:00 - 09:00 Breakfast

09:00 - 10:20 DYNAMICS & OPTIMIZATION
(Chairman: Sine L. Wiggers, SDU, ITI)

POUL G. HJORTH (DTU Compute, 20 minutes)
Pedestrian Dynamics from Social Force Models

KASPER RINGGAARD (AU, Department of Engineering, 15 minutes)
Development of reconfigurable parallel kinematic machining cell for large wind turbine components

CHRISTIAN LUNDGAARD (DTU Mechanical Engineering, 15 minutes)
Topology optimization of thermoelectric energy conversion

FEDERICO FERRARI (guest, DTU Mechanical Engineering, 15 minutes)
Alternative formulation of some eigenvalue problems in topology optimization

JONAS SJØLUND (AAU MAKE, 15 minutes)
Continuous plygroup thickness optimization of offshore wind turbine blades

10:20 - 10:50 Coffee break

10:50 – 12:05 MATERIALS, PROCESS MODELLING, FATIGUE & FRACTURE II
(Chairman: Kim Lau Nielsen, DTU Mechanical Engineering)

KRISTIAN JØRGENSEN JUUL (DTU Mechanical Engineering, 15 minutes)
Numerical Framework for Self-Similar Problems: Indentation in Single Crystals

MARCO MADURO (DTU Wind Energy, 15 minutes)
Effect of different curing schemes on the formation of residual stresses during the production of fiber

ULRICH MORTENSEN (DTU Wind Energy, 15 minutes)
Fatigue damage caused by bending loads in uni-directional non-crimp fibre reinforced polymers

SEYED AYDIN RAEIS HOSSEINY (AAU MAKE, 15 minutes)
Prediction of fatigue damage in tapered laminates

MEHRTASH MANOUCHEHR (DTU Mechanical Engineering, 15 minutes)
Effect of high voltage electric field on the fatigue life of GFRP laminates

12:05 – 13:30 Lunch

14:00 Departure from the hotel

List of Participants

DTU Mechanical Engineering-FAM:
Alexandersen, Joe
Andersen, Rasmus Grau*
Andreasen, Casper S.
Bajric, Anela*
Dilgen, Cetin Bartug*
Felter, Christian Lotz
Ferrari, Federico*
Fogt, Gerda Helene
Groen, Jeroen P.*
Hoffmeyer, David*
Høgsberg, Jan B.
Juul, Kristian J.*
Lundgaard, Christian*
Lynggaard, Julie*
Manouchehr, Mehrtash*
Martinez-Pañeda, Emilio
Møller, Randi Nøhr*
Nielsen, Kim Lau
Niordson, Christian
Nørgaard, Sebastian A.*
Overgaard, Hannibal T.*
Pedersen, Niels L.
Pedersen, Pauli
Poulios, Konstantinos
Sah, Si Mohamed
Sigmund, Ole
Thomsen, Jon Juel
Tidemann, Lasse*
Toftekær, Johan Frederik*
Tvergaard, Viggo
Wang, Fengwen
Yan, Suna*
Zeidan, Said*
Aage, Niels

DTU Compute:
Hjorth, Poul
Mieritz, Andreas F.*
Sørensen, Mads Peter

DTU Diplom
Christiansen, Christian Kim

DTU Electrical Engineering
Jensen, Jakob Søndergaard
Dilgen, Sümer Bartug*

DTU Wind Energy
Jørgensen, Jeppe Bjørn*
Labanda, Susana Rojas
Madsen, Mads Holst Aa.*
Maduro, Marco*
Mikkelsen, Lars Pilgaard
Mortensen, Ulrich*
Sandal, Kasper*
Sarhadi, Ali
Stolpe, Mathias

MAKE
Aalborg University
Andreasen, Jens Henrik
Bak, Brian
Christensen, Simon*
Krogh, Christian*
Ledet, Lasse*
Li, Xuerong*
Lund, Erik
Oest, Jacob*
Raeis Hosseiny, Seyed A.*
Sjølund, Jonas*
Stoltze, Jonas*
Svenninggaard, Jon*
Sørensen, Søren
Wu, Xiaoyong*

CIVIL
Aalborg University
Andersen, Lars Vabbersgaard
Bucinskas, Paulius*
Nielsen, Søren R.K.
Sun, Tao*

Department of Engineering, Aarhus
Balling, Ole
Bräuner, Lars
Heide-Jørgensen, Simon*
Jensen, Henrik Myhre
Juul, Martin*
Madsen, Søren
Ringgaard, Kasper*
Skovsgård, Simon*
Thomsen, Dan*
Vester-Petersen, Joakim*
Zhang, Xuping
Zhang, Zili

ITI
University of Southern Denmark
Andersen, Michael Styrk*
Arora, Vikas
Brandt, Anders
Lützen, Marie
Wiggers, Sine L.

§8-members:
Blasques, Jose
Buhl, Thomas
Redanz, Pia

	Ph.d.	andre
FAM	17	17
DTU Compute	1	2
DTU Diplom		1
DTU Elec. Eng.	1	1
DTU Wind	5	4
MAKE, AAU	10	4
CIVIL, AAU	2	2
ENG, Aarhus	6	6
ITI, SDU	1	4
§8-members		3
	43	44
I alt		87

* Ph.D.-student

Programme for Monday afternoon, March 13th, 2017

1 – DYNAMICS I
(Chairman: Niels Aage, DTU Mechanical Engineering)

13:05 – 14:45 JAN BECKER HØGSBERG (DTU Mechanical Engineering, 20 minutes)

Electromechanical damping of structures.

Electromechanical transducers possess the ability to convert mechanical energy into electrical energy and vice versa. This makes them suitable for energy harvesting and vibration damping of structures. In both applications the electromechanical transducers are placed locally on the vibrating structure, where the straining is substantial, and then calibrated to extract maximum vibration energy.

The vibration amplitudes of flexible structures often exceed the design limits when exposed to resonant loading at a fundamental frequency. Thus, vibration absorbers or resonators may be installed to effectively mitigate the undesirable dynamic response. Electromechanical damping is effectively introduced by supplemental shunts, in which the desired resonance of the absorber is created by a properly balanced inductor-capacitor pair, while energy is dissipate through an additional resistance [1].

A resonant shunt damping strategy is presented, which combines piezoelectric and electromagnetic transducers into a common design format. The shunt components are calibrated with respect to the resonant vibration mode of the structure, based on a suitable compromise between maximum damping and optimal response mitigation. Unfortunately, the influence from non-resonant modes can be quite severe because of the local positioning of the transducers on the structure. This often leads to substantial detuning of the shunt components and thus significant performance reduction. An augmented modal representation is therefore proposed, where the influence from the residual vibration modes is represented by additional flexibility terms, which are determined to exactly reproduce the vibration characteristics in the limit without energy dissipation by the absorber. This extended modal representation results in modified tuning formulae for the shunt components and the accuracy of the shunt damping concept is illustrated by simple numerical examples.

[1] N.W. Hagood and A. von Flotow, Damping of structural vibrations with piezoelectric materials and passive electrical networks, Journal of Sound and Vibration, 146: 243-268.

[2] J. Høgsberg and S. Krenk, Calibration of piezoelectric RL shunts with explicit residual mode correction, Journal of Sound and Vibration, 386: 65-81.

ANDERS BRANDT (SDU, ITI, 20 minutes)

Test and Validation in the Age of Simulation of Dynamics

Numerical models of structural dynamics are notoriously difficult to build correctly, due to the sensitivity to small changes in, particularly, the stiffness matrix. Also, dynamic loads and boundary conditions in operating conditions of, for example, a vehicle or a wind turbine tower, may be difficult to know accurately. Experimental structural dynamics is a field where measurements and methods for validating and calibration of numerical models are developed. This area has developed fast in the last decades, so that we today have relatively efficient methods for both model validation (to see if the

numerical model agrees with experimental data), and calibration (where the numerical model is changed to better agree with the experiemental data). These tools include experimental modal analysis, operational modal analysis, as well as experimental substructuring.
During many years, predictions have been that numerical analysis (FE modelling, typically) and simulation would somehow obsolete test. On the contrary, however, the need for experimental structural dynamics has increased proportionally to the increase in simulations. The presentation will focus on presenting some important structural dynamics tools, and discuss that, and why, it is vital that dynamic models are validated before simulations are performed.

ANELA BAJRIC (DTU Mechanical Engineering, 15 minutes)

Spatial identification of viscous damping from structural vibrations to random excitation

Damping cannot always be obtained from first principles, unlike the stiffness and interia forces. Therefore the mathematical representation of the damping matrix is tuned by damping identified from experimental data. Existing identification techniques for ambient vibrations of real structures are limited to real normal modes, and turn out to be unreliable in identifying damping. A procedure is proposed for identification of non-proportional viscous damping from structural response to random excitation, in the context of linear systems with multiple degrees-of-freedom. Complex engineering structures have non-proportional damping, and posses complex modes. The proposed identification procedure provides an estimate of the non-proportional viscous damping matrix through the complex valued mode shapes and the undamped natural frequencies. The complex valued mode shapes and natural frequencies are identified by the eigensystem realization algorithm, which belongs to a class of output-only system identification techniques assuming broad banded white noise excitation. The efficacy of the method is explored on numerical examples as well as experimentally obtained random vibrations of a five-story shear frame with non-proportional damping induced by an external eddy current damper. The method is suitable for non-proportional damping mechanisms which are viscous and for sufficiently light damping.
Supervisor: Jan Becker Høgsberg

MARTIN JUUL (AU, Department of Engineering, 15 minutes)

Application of Operational Modal Analysis algorithms for System Identification and Finite Element model validation

In a project called INNOMILL, a cooperation between industry partners CNC Onsite, DAMRC and Global Castings, and the Danish universities Aarhus University and DTU we seek to innovate a large scale component flexible machining cell and demonstrate its effectiveness and key performance challenges in simulation and experiments. The main focus is on machining a wind turbine hub.
As a part of the project, a validated Finite Element (FE) model is required. This validation is done using operational modal analysis (OMA) techniques and control of boundary conditions. Control of boundaries effectively isolates the structure from the effects of the surroundings, essentially making a large set of coupled differential equation in closer accordance with the real world.
I explain how acceleration responses from stochastic excitation from the surface of the hub are collected, and present how system identification techniques based on approximate linearity assumptions of the system are

applied to the extensive datasets. Typical algorithms include the Least Squares Complex Exponential (LSCE) and the in Frequency Domain Decomposition (FDD). I present extraction and comparison techniques for mode shapes, show animations for judging if analytical results should be trusted, and comparison of model and identified mode shapes. The techniques make extensive use of autoregressive (AR) modelling, least squares techniques and matrix algebra.

If time permits a small scale model updating example is demonstrated to illustrate techniques for finally updating the FE model based on the measurements.

Supervisor: Ole Balling

XUERONG LI (AAU MAKE, 15 minutes)

Integrated Design and Modelling of an Electro-magnets Driven Spherical Parallel Manipulator

Design of spherical parallel manipulators (SPM) is always a challenge task. In this work, we proposed a novel design of an integrated electro-magnets driven SPM with the advantages of compact structure, no backlash and rapid responds. The proposed SPM uses a circular guide with three-moving slide units which are permanent magnets as the base platform. A number of stator coils which are distributed equally around the guide can interact with the three slide units to actuate the SPM which is shown in Fig. 1. First, the magnetic field distribution of SPM is calculated using the method of magnetic charge mode in order to obtain the interaction between stator coils and the rotor magnetic field. The driving torque model is then presented according to the Lorentz force law. In addition, the forward and inverse kinematics of the SPM are studied. The dynamic model is solved by applying the Lagrange equations. An integrated model is finally built to illustrate the motion of spherical parallel manipulator with Matlab/Simulink with which simulations were conducted.

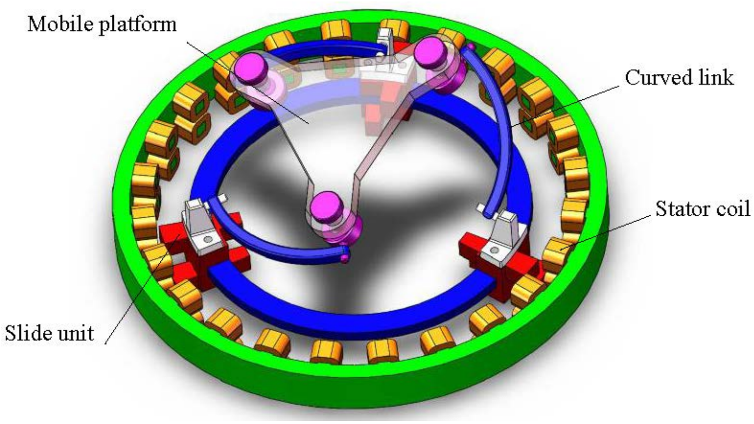

Fig. 1 Integral electro-magnets driven SPM

Supervisor: Shaoping Bai

XIAOYONG WU (guest AAU MAKE, 15 minutes)

Performance evaluation and optimal design of a 3-PPR parallel manipulator

Performance evaluation is one of most important issues in the analysis and optimal design of parallel manipulators. This work presents a comprehensive performance evaluation of a 3-PPR parallel manipulator in terms of kinematic performance, dynamic performance and motion/force transmissibility. For the kinematic and dynamic analysis of the proposed manipulator, the kinematics and dynamic models were derived, with singularity being analyzed. Then a generalized transmission index based on the virtual coefficient was employed to evaluate its motion/force transmissibility. The index can be used to identify a good transmission workspace, where the parallel manipulator is not only good at motion/force transmission but also is far away from its singularity. An optimal configuration for the considered parallel manipulator was finally obtained from the numerical simulation results.

Supervisor: Shaoping Bai

14:45 - 15:15 Coffee break

2 – WIND, FLUID & BIOMECHANICS
(Chairman: Erik Lund, AAU MAKE)

15:15 – 16:35 PIA REDANZ (DNV GL, 20 minutes)

Certification of wind turbines and wind power farms

DNV GL is working with certification of wind turbine types – type certification – as well as certification of wind power farms – project certification. Certification is often requested in order to fulfil national requirements or contractual requirements for e.g. investors. But a number of our customers also simply use certification as a valuable 3rd party check of their turbines or wind farms.

In the first phase of type certification, the turbine manufacturer normally sends us documentation on the design of the turbine, i.e. drawings, structural calculations, load simulations etc. We check the design of the turbine by verifying the customer documentation and by carrying out independent calculations. Another part of type certification is manufacturing evaluation where the connection between the components approved in the design phase and what is actually produced at the factories is checked through manufacturing inspections. In parallel, various measurements are carried out by the customer on e.g. a prototype turbine. These measurements include load measurements, power curve, gearbox field tests and safety & function tests and are used for validating the calculations and assumptions carried out during the design phase. When all certification modules or phases are carried out successfully a full type certificate can be issued.

For project certification of wind farms, the phases consist of assessment of site conditions, design basis evaluation, design, manufacturing, transport & installation, commissioning and in-service. The site condition assessment includes check of wind, waves and geo-technical conditions for the wind farm. In the design phase, the design of support structure, foundation, loads and geo-technical conditions are checked including the interaction with the turbine. As for type certification, when all project certification modules have been carried out successfully a full project certification can be issued.

ANDREAS FALKENSTRØM MIERITZ (DTU Compute, 15 minutes)

High performance computing of nonlinear modulations of carrier waves in optics and water waves

Spectral white light is used in Optical Coherence Tomography (OCT) systems for e.g. medical diagnostics purposes. A powerful way of generating a broad band white light source is to use supercontinuum generation in nonlinear optical crystal fibers illuminated by a monochro-matic laser. In this presentation we shall discuss the development of a new generation of supercontinuum light sources with unprecedented low noise and shaped power spectra that are optimal for use in the next generation ultra-high resolution Optical Coherence Tomog- raphy (UHROCT) systems.

In this presentation the main focus is on invoking high performance computing of the generalized nonlinear Schrodinger equation for aiding the optimal design of supercontinuum generation. Our model includes higher order dispersion, delayed Raman response and tapering in order to construct fiber design features for reducing the noise in a supercontinuum light source and shape its spectrum.

The overall goal is to use UHROCT for cost effective diagnose of glaucoma, the second leading cause of blindness worldwide, and to develop equipment easy to use for a local clinic contrary to current practice. The project is

conducted in collaboration with NKT Photonics, designing supercontinuum and OCT systems, and Bispebjerg Hospital, Denmark.
Supervisor: Mads Peter Sørensen

MICHAEL STYRK ANDERSEN (SDU, ITI, 15 minutes)
Estimation of flutter derivatives for B/D=10 rectangular section
Coupled free vibration tests are used to estimate the flutter derivative for a rectangular section with a width-to-depth ratio B/D = 10. The flutter derivatives are estimated at wind speeds ranging from still air to wind speeds above the critical utter wind speed. Several different torsional-to-vertical frequency ratios have tested. In the case where the torsional natural frequency are lower than the vertical, the flutter derivatives are estimated at very high reduced wind speeds because of the stable behavior of the section. This does not seem to cause significant deviations compared to the flutter derivatives estimated when the torsional natural frequency is higher than the vertical.
It is shown that positive aerodynamic damping occurs in the torsional dominated mode at high reduced wind speeds while negative aerodynamic damping occurs at lower wind speeds. This implies that torsional flutter can occur for lightly damped B/D=10 sections with low mass moment of inertia and that both torsional and coupled flutter can be avoided if the equivalent mass moment of inertia is increased and the torsional natural frequency becomes lower than the vertical.
Supervisor: Anders Brandt

JONAS STOLTZE (AAU MAKE, 15 minutes)
On the biomechanical relationship between external hip, knee and ankle joint moments and the internal knee compressive foreces
Knee Osteoarthritis (KOA) is often treated using a valgus brace, which has the purpose of reducing the internal joint load in order to unload the damaged structure. However, this load reduction is achieved by shifting the load from the medial to the lateral compartment, without changing the total compressive load. The aim of this study was to investigate how internal knee joint loads depend on applied external moments during gait, which can be useful information for improving knee braces.
Musculoskeletal models of ten healthy subjects, performing gait trials, were developed in the AnyBody Modelling System (AMS). Joint moments and combinations (referred to as load cases) of these were applied about different axes, each with the magnitude to fully compensate the net moment about the respective axis. For each load case, the total, medial and lateral knee compressive force were computed and compared with a baseline case with no external moments applied.
The results showed, as expected, that the current valgus brace method does not reduce the total compressive load but only shifts the load from one compartment to the other. Among the investigated moments, hip flexion-extension, knee flexion-extension and ankle plantarflexion-dorsiflexion moment compensations have the most positive impact on the total knee joint compressive force. Combining those three, reduces the first peak by 51.9%, the second peak by 60% and the impulse by 59.4% with respect to baseline.
Supervisor: Michael Skipper Andersen

SIMON CHRISTENSEN (AAU MAKE, 15 minutes)

Design of an upper-body exoskeleton using musculoskeletal simulations

Advancements in robotic exoskeleton technology towards human assistance have made it possible for weakened elderly people to maintain their life standards. An exoskeleton is a mechanical system that runs in parallel with the human. For rigid upper-body exoskeletons, the main design challenge is to achieve good physical human machine interface. A human arm exhibits highly dexterous motions; it can reach out for an object or perform any particular task in numerous ways. Preserving the dexterity, in this case by being kinematic compatible, is one of the biggest challenges in designing assistive upper-body exoskeleton. Kinematic incompatibility can lead to locking, chafing and unintentional joint loads. Using musculoskeletal simulations, we are able to study the effects the exoskeleton has on the human biomechanics, determine the power requirements of the actuators of the exoskeleton and estimate the interaction forces between the human and exoskeleton. From the musculoskeletal simulations, we designed 4-DOF upper-body exoskeleton composed by a shoulder and elbow joint and attachments at the torso, upper arm and forearm. The exoskeleton was examined by end users in a usability test, where exoskeletons ability to complete basic movement and level of comfort during the movements were evaluated.

Supervisor: Shaoping Bai

16:45 – 17:30 POSTER PRESENTATIONS
(Chairman: Mathias Stolpe, DTU Wind Energy)

17:30 – 19:00 POSTER SESSION

SIMON HEDE-JØRGENSEN (AU, Department of Engineering)

Crack Growth Along Heterogeneous Interface During the DCBB Experiment

Interface and bondline heterogeneities are inherent parts of laminated materials. Recently these, otherwise unwanted, features are gaining importance enhanced by the surface patterning techniques. In the present contribution, double cantilever beam adhesion experiment is performed on joints with patterned interfaces. Weak/strong adhesion bands perpendicular to the crack growth direction are produced along the bonded surfaces. A vast range of specimens with different but systematic weak/strong zones ratios is tested. A novel analytical model, including a rule of mixture scaling, is developed to gain phenomenological insights of the data obtained. Two specfic cases are addressed; a single strong/weak transition and multiple transitions. The new model proves in very good agreement with the experimental data obtained for any configuration tested. The role of three length scale parameters: weak, strong and process zones sizes, and their interactions, are emphasized. For instance, once small (in comparison to the process zone size) weak/strong zones are present a substantial decrease in the fracture energy is recorded. This observation may be of possible importance in understanding both, natural (e.g. geckos feet) and industrial (laminated and bonded materials) bondline discontinuities including the role of fillers, voids or kissing bonds.

Supervisor: Michal Budzik

SIMON SKOVSGÅRD (AU, Department of Engineering)

Modelling of Failure in Composite Materials

1. Introduction

Fiber composites loaded in tension have high stiffness and strength, but when loaded in compression the critical stress is considerably lower than in tension. Structural components loaded in bending are exposed to both tension and compression and since the critical stress is lower in compression this is the failure mode which should be used as a design load.

Several studies have been made in mapping the different failure modes of fiber composites in compression. The most frequently observed failure is due to plastic microbuckling which is a material instability and results in kink band formation. These are bands of material where the fibres inside the band have rotated relative to fibres outside the band. Kink band formation as a failure mechanism is observed in unidirectional fibres as well as in multi layered composites with different layups inside the individual layers.

The critical stress for kink band formation is known to be sensitive to structural imperfections such as misalignments of the fibres relative to the load direction. This make theoretical investigations of kink band formation challenging as they must involve full, non-linear finite element simulations allowing for all possible non-linear behaviour of the constituents as deformation evolve.

2 Objectives

The objective of the PhD is to add knowledge to the field of material mechanics of fibre composites with focus on stability of fibre composites loaded by compression. Such objectives require knowledge about nonlinear

computational models including nonlinear material and geometrical behaviour.
The present work aims at investigating the behaviour of a constitutive relation implemented in the commercial software Abaqus as a user subroutine.
This constitutive implementation accounts for the material nonlinearities due to plasticity and account for the anisotropy of a unidirectional fiber composites.
Supervisor: Henrik Myhre Jensen

DAN THOMSEN (AU, Department of Engineering)
Vibration suppression with input shaping
Modern machinery is required to move with high velocities and accelerations while maintaining a low weight and power consumption. The high accelerations in flexible structures introduce unwanted dynamic behavior in the form of residual mechanical vibrations and new approaches to suppress or reduce these vibrations are being sought. One of the methods which are drawing attention in recent research is input shaping.
By delaying a portion of the input command to your system, it is possible to cancel out vibrations with a specific well known frequency. This approach is superior to low pass filtering when comparing the time cost of vibration suppression. The downside is that the system dynamics must be well known.
Input shaping is fully feed forward and requires no additional sensors or actuators.
Different approaches to determining and increasing the robustness to modeling errors will be presented with simulation results for a linear time-invariant dynamic system.
Supervisor: Xuping Zhang

TAO SUN (AAU, Civil Engineering)
Stochastic optimal control of a point heave wave energy converters
Significant increase of the generated power of point wave energy converters may be achieved by the use of active control of the power take-off system. Generally, there are constrains on the motion of the absorber due to the limited stroke of the actuator of the control system. Similarly, the available control force will be constrained between certain limits. In this presentation the basis is the control of a heave point controller ignoring such constraints. Further, linear wave theory is assumed. A theoretical solution for the indicated control problem is available, which turns out to be a feedback controller, with feedback from the instantaneous acceleration and the displacement of the absorber, and a non-causal feedback from future velocities in terms of a convolution integral. At practical applications the future velocities need to be predicted, rendering the controller causal and sub-optimal. In order to use Kalman filtration for optimal prediction the convolution integral and the external wave load are replaced by rational filters, representing the total system on a linear state vector form driven by unit intensity Gaussian white noise. The sub-optimal solution will be compared to optimal controller, where the numerical results are obtained by nonlinear programming.
In the next step the optimal constrained problem will be considered. Semi-analytical solutions will be derived, which will be compared to those obtained by nonlinear programming and the numerical solution of the stochastic Hamilton-Jacobi-Bellman equation with state constraints.
Supervisor: Søren R.K. Nielsen

PAULIUS BUCINSKAS (AAU, Civil Engineering)

Fully coupled Model of Ground and Building Vibration

Determining the vibration levels inside a building is an important task when designing new structures or renovating already existing ones. However, the vibration levels inside a building are a complex phenomenon to predict. They are affected not only by the design choices of the building in question, but also the surrounding environment with the already existing structures, various vibration sources and geotechnical conditions. Therefore, computational tools that consider vibrations propagation in the soil and the effects of soil–structure interaction are needed.

Unfortunately, numerical modelling of the ground is difficult, due to the unbounded nature of the soil body. Therefore, finite-element (FE) based methods require special boundary conditions and large computational domains to represent the soil body. However, a semi-analytical approach is possible, by utilizing an analytical solution for the Green's function in frequency–wavenumber domain, with a numerical transformation to spatial domain. This way it is possible to only consider the structure–soil interaction points, for which a dynamic stiffness matrix is obtained in the same format as in FE approaches.

A computational model is obtained where the structures interacting with soil can be modelled using finite elements, while the soil is modelled with the semi-analytical approach. The final solution is a computationally efficient fully coupled model to model the ground and building vibration.

Supervisor: Lars Vabbersgaaard Andersen

LASSE LEDET (AAU MAKE)

Vibro-acoustics of centrifugal pumps

Through this poster the outline of the recent Industrial PhD project within vibro-acoustics of centrifugal pumps and its transmission into the receiving piping system will be presented in brief. The project is a collaboration between Grundfos Holding A/S and Aalborg University.

The motivation of this project emerge in view of the recent tendencies for scaling all types of pumps to operate in a wider span e.g. at much higher nominal flow and pressure, but likewise pumping more complex fluids such as waste water. Unfortunately, the vibration levels scale faster than proportionally with the dimensions and nominal flow/pressure conditions and in addition, the maximum allowable pressure pulsations and vibration levels decrease with increasing pipe dimensions. Thus, it is an everlasting challenge to comply with prescribed vibration and pressure pulsation levels.

These vibro-acoustic properties of a centrifugal pump are highly dependent on dimensions, operational regimes and boundary conditions., why the objective of this project is to formulate and employ simple models that can, eventually, be used as a design tool to point the direction of vibration optimised designs prior to prototype tests and further to enhance our understanding of generation of vibro-acoustic energy in rotating machinery both as stand-alone and in an assembled pipeline. To accomplish this, the spatial distribution and intensity of sources of vibro-acoustic energy in pumps and the partition of energy between alternative transmission paths need to be identified and quantified. Fast accurate predictions of these vibro-acoustic performance characteristics are not possible with today's methods; however, this is of greatest importance for Grundfos as to significantly raise the market standard, expedite product releases, shorten design cycles etc. Another important objective is to enhance the understanding of the multiphysics phenomena of fluid-structure

interaction in view of generation and transmission of vibro-acoustic energy at the blade-passing frequency (BPF), which is yet to be explored fully in the pump industry.
Supervisor: Sergey V. Sorokin

CHRISTIAN KROGH (AAU MAKE)

Modeling of Prepregs during Automated Draping Sequences

Composite parts made from pre-impregnated fiber mats, so-called prepregs, are frequently used in the aerospace industry due to their superior mechanical properties. Currently, woven prepregs are manually placed into a mold prior to curing. The manual layup process is costly and can yield significant quality variations in the final part. Thus, an automated layup solution is under development where a robot can manipulate and drape the prepregs into the mold.

The success of this implementation relies on both accurate and computationally efficient models describing the mechanical behavior of the prepreg material which is the scope of the PhD project. The models will aid in generating feasible robot trajectories, i.e. draping sequences. Here feasible entails that the fiber plies do not deform undesirably while being manipulated by the robot as well as drapes onto the mold without wrinkles, air pockets and other defects. The models must, among other things, account for the non-linear anisotropic constitutive behavior, viscoelasticity, possible plasticity, and contact which includes friction between the ply-mold and ply-end effector interfaces. The problem is path dependent and thus the transient aspect of the draping must be taken into account.

The accurate modeling is accomplished with an explicit Finite Element (FE) scheme with shell elements. Material characterization in the form of uniaxial tensile tests, bias-extension tests (45 ° tensile test) and bending tests provide input for the model. With basis in an experimentally validated FE model and with improved knowledge of the mechanics of the plies, more efficient models and/or simple wrinkling criteria are to be developed at a later stage.
Supervisor: Johnny Jakobsen

JON SVENNINGGAARD (AAU MAKE)

Test fixture for double cantilever beam (DCB) specimens subjected to uneven bending moments

With the increased use of modern lightweight materials like layered fibre reinforced polymers there is an inherent demand to characterize their properties. One of the critical failure modes in layered materials is delamination due to the low out of plane strength. To characterize the interface strength in layered materials the cohesive law and fracture strength must be known. Ideally the entire cohesive law is known in order to aid in the design of components and structures.

In this work we present a novel test fixture which can be used to test DCB specimens that are subjected to pure Uneven Bending Moments as a function of the phase angle ranging from mode I to mode II loading including mixed modes in-between. The test fixture utilizes an existing tensile testing machine and can subject specimens to loads up to 350 Nm. The test fixture is compact in size and designed using standard aluminium profiles for the main structure. The load is transferred from the test machine to the specimen through a 2 mm Dyneema rope. The rope is routed over a set of rollers that are positioned according to the specified mode mixity and phase angle.

The kinematics of the test fixture has been analysed extensively as well as a

specially fabricated tool, made from two flat bars, which was fitted with strain gauges to verify that the strain field from the pure moment application. The analysis revealed negligible introductions of shear forces to the specimens.
Supervisors: Jens Andreasen, Esben Lindgaard & Brian Bak

MADS HOLST AA. MADSEN (DTU Wind Energy)

High Fidelity CFD-based Shape Optimisation of Wind Turbine Blades

Background and scope of project

In order to design airfoils and blades with an optimized energy production and noise emission wind energy researches rely heavily on aerodynamics as well as aeroacoustics. The industry have turned to (simplified) mathematical models to minimise the duration of new products' design cycles. Said models are then verified against experimental results as well as the more time costly, high-fidelity CFD-based simulations. A natural next step is therefore to provide the wind energy industry with the means to use high-fidelity routines already in the design cycles - thus following suit with the aeronautical and automotive industries [1, 2]. This is precisely the scope of the overall project.

Project Milestones

It has been known for decades that the adjoint method offers an efficient way to shape-optimise an aerodynamic profile [3]. Indeed, this method has been called the "tool of choice for gradient-based optimisation" [1, p. 1] but its application within wind energy is still immature. Interestingly, recent publications on shape optimization of the NREL VI wind turbine blade for 50 [4] and 251 [5] design variables for respectively the continuous approach and the discrete approach have been reported. In the latter and most recent Ref. the time for a design cycle was kept below 24h when using 256 cores. Thus proving that the industry could be given the means to shape-optimise on a daily basis. To this end the present project can be divided into the following milestones:

1. Geometry parameterisation module
2. CFD-mesh deformation algorithm
3. An adjoint solver
4. Integrate components 1-3 in a gradient-based optimisation framework

Current work

The first four months of the project have been dedicated to literature study, courses and implementation of (1) Geometry and (2) Deformation tools. Currently, a prototype algorithm using the Free-Form Deformation [6] has been implemented for the former whereas the latter is based on a FVM Linear Elasticity algorithm.

Outlook

The most logical next step would be to combine the (single discipline) adjoint based aerodynamic shape optimizer with a structural counterpart to obtain a Multi-Disciplinary Design Optimisation (MDO) framework which currently is the state-of-the-art within the aeronautical industry. The adjoint method is however very general and can easily be applied to a great number of topics, e.g. wind farm design [7].

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Supervisor: Frederik Zahle

SÜMER DILGEN (DTU Electrical Engineering)

Topology optimization of acoustic-structure interactions problems

Small acoustic devices such as hearing aids and mobile phones are particularly sensitive to acoustic-mechanical interaction. This interaction has a strong influence on the performance which is often limited by the feedback mechanism occurring when amplified sound is picked up by the microphones and re-amplified. For the design of mechanical systems, topology optimization has been recognized as a very valuable design tool and often leads to unconventional and novel design concepts. However, there are significant challenges when applying free material distribution in coupled problems such as acoustic-mechanical interaction. Topology optimization based on mixed Finite Element model, remedies some these challenges by allowing the structural parts of the device to turn into acoustic parts and vice versa.

Alternative methods based on different design descriptions or optimization schemes also appeared in the literature. Current state-of-the-art methods all offer potentials but also problematic issues. Thus, further development towards a robust and versatile optimization procedure is needed. The goal of this project is to bring the application of topology optimization for acoustic-mechanical interaction problems a significant step further by developing the most appropriate design parametrization scheme and to apply it to complex structures.

Supervisor: Jakob Søndergaard Jensen

RANDI NØHR MØLLER (DTU Mechanical Engineering)

Wind Field Simulation by Low Order ARMA Processes

In the design of long span bridges the maximum achievable span length is limited solely by requirements to aerodynamic stability. The longest suspension bridge in the world is the Akashi-Kaikyo Bridge, Japan, which has a main span length of 1991 meters. However, an interest in pushing the limit for span lengths of long cable supported bridges even further is present, e.g. in relation to the Norwegian infrastructure project Ferjefri E39 that contains at least three major fjord crossings where span lengths are likely to exceed 2000 meters. Due to the interest in building even longer bridges, it is relevant to determine the aerodynamic stability limit more precisely and thereby minimize conservatism in the calculations. This project is concerned with improving the calculation method through a consistent representation of the turbulent wind loading and an improved method for evaluation of the time domain response of the aero-elastic bridge structure.

For long span bridges the correlation structures in the turbulent wind field are essential for the structural response. A generally used simple exponential description of the coherence function inconsistently implies full correlation of the low frequency wind components as well as a non-zero mean represent-tation of the along wind fluctuating component. A precise stability limit calculation for long-span bridges where the span length exceeds the true correlation length of the low frequency wind should however include a consistent representation of the fluctuating wind.

The wind field representation serves as input to a stability analysis of the bridge structure in the time domain. The classic representation of the wind-structure interaction is in terms of flutter derivatives in the frequency domain, or equivalently convolution integrals in terms of the so-called indicial functions in the time domain. Convolution integrals are notoriously computationally expensive and it is desirable to replace these by introducing the aerodynamic interaction forces as additional state-space variables in the analysis, and characterize them via first order differential equations. For evaluation of the structural response it is considered important to develop an efficient and accurate time integration algorithm with particular emphasis on the energy balance of the system and including an appropriate algorithmic damping implementation for the suggested extended system.

Supervisor: Steen Krenk

DAVID HOFFMEYER (DTU Mechanical Engineering)

Damping of Torsional Beam Vibrations

Slender structures like long bridge decks, aircraft wings, wind turbine blades and general thin-walled beams may be prone to aerodynamic instabilities like flutter, where flexural and torsional vibrations couple. Torsional vibrations occur if the loads on a beam act with an eccentricity relative to the shear center of the beam cross-section, and for beams with asymmetric cross-sections flexural and torsional vibrations couple. Flutter is associated with apparent negative damping that cannot be sufficiently compensated by the inherent structural damping. To avoid flutter, to reduce fatigue stresses by aerodynamic forces and to damp vibrations that include torsional elements – supplemental damping is required.

Inhomogeneous torsion of thin-walled beams is associated with out-of-plane, axial warping displacements that are often significant at the boundaries of beams with open cross-sections. Thus, for these types of thin-walled beams the restraining of warping results in an often considerable increase in natural frequency and change in vibration characteristics. The localized effect of restrained warping is utilized to introduce a substantial amount of supplemental damping, by applying viscous boundary conditions through pure bimoments at the supports. An eigenvalue problem associated with free vibrations occur when solving the governing differential equation, and results in the complex-valued natural frequency and corresponding damping ratio.

A linear finite element model with three-dimensional, isoparametric elements is established in order to compare numerical results with the analytical differential equation. In a simple numerical code, the bimoments are easily represented by concentrated, axial forces distributed over the cross-section in a self-equilibrating configuration. These viscous forces are proportional to the velocity of the given node and are added to the equations of motion by an influence vector describing the points of application.

It is demonstrated that considerable damping ratios are obtained for beams with open cross-sections, while for beams with closed cross-sections the realized damping ratios are much smaller due to the less pronounced warping displacements.
Supervisor: Jan B. Høgsberg

JULIE LYNGGAARD (DTU Mechanical Engineering)
Modeling injector related hydraulic fracturing with focus on the Halfdan field in the North Sea
Modeling tools for hydraulic fracturing following water injection, with focus on the Halfdan oil field in the North Sea are developed. The field is produced from a series of parallel horizontal wells, alternately injectors and producers. The regular periodic well pattern, and the fact that a "layer-cake" model of the subsurface is applicable for Halfdan, means that the fluid flow, and the stresses and strains generated by the flow, can be analyzed with reference to a cross section perpendicular to the wells, where conditions of plane strain applies. This makes the field ideal for detailed modeling and comparison with seismic data. Poroelasticity is employed to model the stress and flow fields as well as the size of the vertical fractures, while Darcy's law is used to describe the fluid flow. Chalk has very low fracture toughness, and for simplicity it is assumed that it will fracture under tensile loading. Furthermore it is assumed that the chalk will fracture as an isotropic homogeneous material, and the fractures propagate perpendicularly to the maximum positive principal stress.
Numerical solutions are obtained using the Finite Element Method for poroelasticity. The influence of key material and loading parameters is investigated, and implications for sweep efficiency are brought forward.
Supervisor: Christian F. Niordson

RASMUS GRAU ANDERSEN (DTU Mechanical Engineering)
Numerical analysis of Ductile Plate Tearing under Mixed Mode Loading
Large ductile plates are widely used in many structures, e.g. airplanes, vessels, and cars. Thus, accurate models to predict crack initiation and growth are crucial to push technological boundaries. Under specific loads in the structure, cracks can initiate and preserved or increased load magnitudes in the structure cause the cracks to grow and compromise the structural integrity. The loads can develop in any direction and can even be multi-axial due to the complexity of most structures.
In the modeling of plate tearing in large plate structures, shell elements together with cohesive elements embedded in the direction of fracture, are often employed. Here with the cohesive elements defined from simplified traction-separation relations. This is a phenomenological and simplistic approach of dealing with complex material failure but nonetheless it is often the preferred approach in the industry due to the reasonable computational costs. Unfortunately, the model response then heavily rely on the assumptions made for the cohesive zone elements.
The current study will investigate steady-state ductile plate tearing under complex mixed mode loading conditions and dig into accurately quantifying both the cohesive fracture energy, the peak stress as well as the appearance of the traction-separation law. In addition, also the crack initiation until the steady-state crack growth will be investigated together with the path dependency for different fracture modes.

The aim is to shed light on the cohesive fracture energy necessary for crack growth in large plate structures both concerning crack initiation and subsequently the steady-state plate tearing.
Supervisor: Kim Lau Nielsen

JOHAN TOFTEKÆR (DTU Mechanical Engineering)
Vibration Suppression of Plates by Optimally Placed and Calibrated Piezoelectric RL Shunt Damping
The present paper concerns vibration suppression of plate structures, characterized by having relatively large stiffness-to-mass ratios and thus dominating natural frequencies, associated with for example acoustics and noise, that are larger than typical for large-scale structures. This makes the use of mechanical damping devices, such as dashpots, springs and auxiliary vibration masses, infeasible for vibration suppression. Instead electromechanical device, with the ability of transforming mechanical energy to electrical energy (and vice versa), have emerged as a favorable alternative. Piezoelectric transducers, patches or laminates can be attached locally on a structure, where they, due to their fairly large force-to-deflection ratios, efficiently dissipate energy at small deformation rates. Regarding plate structures, the relative displacements of a locally attached piezoelectric patch become two-dimensional, making them particularly suitable as supplemental dampers due to their orthogonal material properties [1]. The piezoelectric patch can be designed both as an active actuator, where the patch is controlled by an externally applied voltage, or as a passive device with mechanical to electrical energy conversion governed by the electromechanical coupling effect and a supplemental electrical shunt. The active control is often limited by the requirement of power supply and control instabilities, motivating the use of passive shunt damping.
Resonant piezoelectric damping is introduced by an inductive-resistive (RL) shunt, for which the performance relies on the precise calibration of the shunt frequency. Thus, an important aspect of passive shunt damping of flexible structures like plates is the ability to account for the energy spill-over from the non-resonant modes, which is not taken into account by common calibration procedures. The importance of the non-resonant modes for the optimal calibration increases for patches located indirectly with respect to the deformation pattern of the targeted mode.
The objective of the paper is the suppression of plate vibration by means of piezoelectric RL shunt damping, optimally tuned by the calibration procedure described in [2] for beams, where the spill-over from non-resonant vibration modes is included by a quasi-dynamic modal correction, taking both flexibility and inertia effects from the residual modes into account. The procedure is extended to include the 2D behaviour of a shunted piezoelectric patch, represented in a finite element model with Kirchhoff plate kinematics. The optimum positioning of a piezoelectric patch is determined for particular vibration modes by maximizing the electromechanical coupling coefficient that is also modified by the residual mode correction. Furthermore, the ability to reproduce the desired level of attainable damping is demonstrated for indirect placement of one or more patches. The accuracy of the quasi-dynamic calibration procedure is investigated for a plate structure, in particular with respect to closely spaced modes.

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Supervisor: Jan B. Høgsberg

CETIN DILGEN (DTU Mechanical Engineering)
Transient Optimization of Acoustic-Mechanical Interactions Problems
Design optimization is an essential ingredient to achieve future demands for outstanding performance of acoustic devices such as hearing aids and mobile phones. However, challenges exist in the quest for performing advanced optimization studies on large- and giga-scale models when considering vibration problems of coupled systems as found in the case of acoustic-structure interaction. Current state-of-the-art methods are usually based on frequency domain analysis, but when the size of the considered problems increases serious issues with this approach are known to arise. Additionally, advanced dynamic effects caused by non-linearities are cumbersome to include in the analysis. A promising alternative to overcome these diffculties is to employ transient or time-domain analysis to study the coupled acoustic-structural problem and to use such simulations as the basis for the subsequent optimization. An additional benefit of the transient simulations is the ability to include nonlinearities with relative ease in comparison to frequency domain analysis. The goal of this project is to develop a transient optimization framework for coupled acoustic-mechanical interaction problems, apply this to large and ultra-scale models and extend the model with structural/coupling nonlinearities.
Supervisor: Niels Aage

HANNIBAL TOXVÆRD OVERGAARD (DTU Mechanical Engineering)
Lubricant transport across the piston ring in large two-stroke marine diesel engines
A theoretical investigation of the lubricant transport across the top compression piston ring in a large two-stroke marine diesel engine is presented.
A numerical model for solving Reynolds equation between the piston ring and cylinder liner based on the finite difference method in 1D has been made. The model includes force equilibrium of the piston ring, perturbation of Reynolds equation and transient mass conservation. The model represents a new method of achieving mass conservation across the piston ring and between different time dependent positions.
For analyzing the lubricant transport across the piston ring two different kinds of initial lubricant profile on the liner and two different kinds of load are investigated i.e. a flat profile and an approximated triangular profile as well as no load and a combustion load based on a combustion pressure profile.
The impact from the different load conditions and different lubricant profiles on the liner are presented for film thicknesses, development in the lubricant profiles on the liner as well as the lubricant consumption at each stroke.
Supervisor: Peder Klit

19:00 - Dinner

Programme for Tuesday morning, March 14th, 2017

3 – OPTIMAZATION - I
(Casper Schousboe Andreasen, DTU Mechanical Engineering)

09.00 – 10:45 KASPER SANDAL (DTU Wind Energy, 15 minutes)
Conceptual optimal design of jacket structures for offshore wind turbines

The paper presents an approach for conceptual optimal design of jacket structures, see Figure 1, and applies it to investigate the influence of leg distance on jacket mass.
A four-legged jacket for the DTU 10 MW wind turbine in 50 meter water depth is modelled by Timoshenko beam finite elements, and the dimensions of the jacket cross sections are considered as design variables. A structural optimization problem is formulated to minimize the jacket mass, with constraints on fatigue and ultimate limit states.
Optimized jacket designs lie in the range 650-1000 tons, depending on the leg distance at the bottom and top of the jacket, and on the number of independent cross section areas. The presented design software, JADOP, gives an automated procedure for conceptual jacket design, and solves the modelled optimal design problems.
Supervisor: Mathias Stolpe

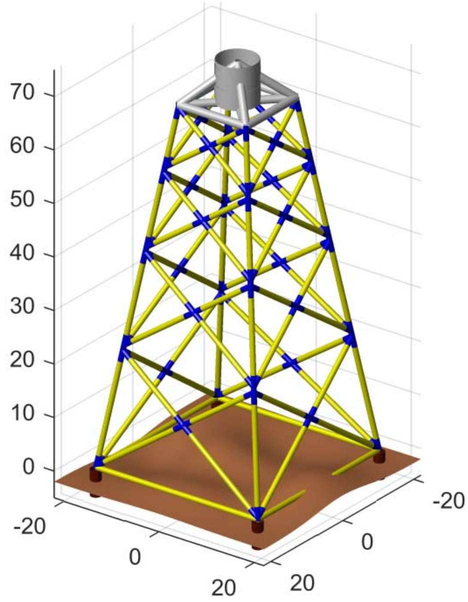

Figure 1: A four-legged jacket structure for offshore wind turbines.

JACOB OEST (AAU MAKE, 15 minutes)
Topology optimization with quasi-static fatigue constraints using an effective adjoint formulation

Structures subjected to cyclic loading are prone to fatigue failure. Improving a structural design with regards to fatigue is not always straightforward. Thus, topology optimization for fatigue can be a powerful design-tool in the early design phase. Some of the difficulties in topology optimization with fatigue constraints are vanishing constraints, large load series, and the local and highly non-linear behavior of fatigue damage, which makes the optimization problem computationally costly and difficult to solve.
In this work, topology optimization by minimization of mass subject to finite-life fatigue constraints is solved using the density approach and the Method of Moving Asymptotes. The design domain is discretized using linear finite element theory, and the fatigue damage is estimated using the Sines criterion in combination with Palmgren-Miner’s accumulation rule. The computational cost is reduced by aggregation functions and an analytical adjoint formulation of the sensitivities, where the amount of adjoint equations is independent of the amount of stress cycles in the load spectrum. Consequently, large load series can efficiently be applied in the optimization, with the restriction of proportional loading and a quasi-static analysis. Benchmark examples will be presented, and results are compared to stress constrained designs.
Supervisor: Erik Lund

SAID ZEIDAN (DTU Mechanical Engineering, 15 minutes)

Topology optimization for transient heat transfer problems

This work utilizes the topology optimization method to obtain efficient thermal control of transient heat transfer problems. The goal is to obtain distributions of two or more materials in selected design domains, where the distributions are optimized with respect to given objectives.

The optimized design rely heavily on the property of phase change materials (PCM) to effectively absorb and release latent heat while keeping its sensible temperature nearly unchanged [1]. PCM are widely utilized in electronics , mechanics, civil engineering [2], [3] and [4], leading to improved performance at potentially lower cost which depends on the PCM volume and distribution.

The optimized distribution is obtained by a gradient based iterative technique. Every optimization step requires the solution of an unsteady heat problem which is obtained using the finite element method for the spatial discretization and a finite-difference based time stepping scheme [5]. The gradients are obtained by solving the associated time dependent discrete adjoint system. The PCM model is based on the effective heat capacity model [6].

The considered numerical examples represent several real time scenarios, e.g., controlling the temperature variations in a room subjected to temporally varying ambient temperature [7] or a general minimization of the heat loss in thermal energy storage [8]. The aim is to obtain manufacturable designs with performance that is insensitive with respect to input variations and manufacturing uncertainties [9].

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Supervisor: Ole Sigmund

JEROEN PETER GROEN (DTU Mechanical Engineering, 15 minutes)

Homogenization-based topology optimization for high-resolution manufacturable micro-structrues

The objective of this work is to present a projection method to obtain high-resolution manufacturable structures from efficient and coarse-scale, homogenization-based topology optimization results [1]. The focus of this work is on compliance minimization of linear-elasticity problems, for which it is known that the optimal solution is in the space of layered materials, the so-called rank-n laminates. Here rank-2 laminates are optimal for plane problems subject to a single load case, and rank-3 laminates are optimal for plane problems subject to multiple load cases.

In a very appealing approach, Pantz and Trabelsi introduced a method to project the microstructures from homogenization-based topology optimization to obtain a solid-void design with finite length-scale [2]. The local structure is oriented along the directions of lamination such that a well-connected design is achieved. This approach paves the way for coarse-scale topology optimization where the projection can be performed on a high-resolution mesh in a post-processing step, without a need for cumbersome and expensive multi-scale formulations.

This work shall be seen as a simplification and improvement of the approach introduced by Pantz and Trabelsi [2]. We simplify the projection approach and introduce procedures for controlling the size and shape of the projected design, such that high-resolution (e.g. 1 million elements in 2D), near-optimal and manufacturable lattice designs for single and multiple loadcase problems can be achieved within a few minutes using a single processor Matlab code on a standard PC.

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Supervisor: Ole Sigmund

JOAKIM VESTER-PETERSEN (AU, Dept. of Engineering, 15 minutes)

Topology optimized light focusing nano particles

This work is a part of the SunTune project [1] which addresses efficiency improvements of solar modules by manipulating the spectrum of sunlight to better match the range of efficient current generation in silicon solar cells. Photons with energies below the band gap energy of silicon (< 1.1eV) are converted into photons with higher energies through absorption in rear earth ions (Er^{3+}) followed by radiative decay. This process converts otherwise non-absorbed long wavelength photos to shorter wavelength photons able to bridge the band gap energy and contribute to the energy generation of the solar modules.

The upconversion process is naturally inefficient, and without any enhancement of the incident light, the process is negligible. The probability for upconversion can be increased by focusing the incident light into areas doped with Er^{3+} ions, using optimized nanoparticles placed into or near these areas. [2] showed that the intensity of the upconverted light, I_{UCL} is proportional to the intensity of the incident light, I_{in} raised to some power, n, $I_{UCL} \propto I_{in}^{n}$. Where n is experimentally found to be $n = 1.5$, and in general $I \propto |E|^2$.

Using gradient based topology optimization the two-dimensional distribution of nanoparticles, consisting of either silicon or gold is modified to enhance $|E|^3$ in a thin Er^{3+} doped TiO_2 film. The governing physics is modeled classically using Maxwell equations in a finite spatial domain truncated using periodic boundary conditions. The model is excited by an incoming plane wave with a wavelength, λ, within the absorption band of Er^{3+}, 1480nm $\leq \lambda \leq 1560$nm. Topology optimization has previously proved successful in optimizing wave propagation, and electromagnetic problems [3, 4, 5] and is therefore the method of choice in this work.

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Supervisor: Søren Madsen

SEBASTIAN A. NØRGAARD (DTU Mechanical Enginnering, 15 minutes)

Topology optimization of heat regenerators using the lattice Boltzmann method

Thermal regenerators are a type of heat exchanger, which have applications in areas such as cryocoolers, dehumidifiers, solar power, magnetic refrigeration and more. There already exist several classes of accepted engineering designs for the these devices, such as stacked plates or packed beads of material, which serve as the heat absorbing medium of the regenerator. These existing designs have different trade-offs in terms of efficiency and pressure drop.

While the stacked plate design theoretically offers high thermal performance at low pressure drop, the experimentally observed performance is typically lower than what theory predicts; this is generally attributed to flow mal-distribution as a result of non-uniform plate widths. The non-uniformity is typically caused by manufacturing errors. Thus, the goal of the presented research is to apply the topology optimization methodology to obtain regenerator designs which have robust performance in spite of potential manufacturing errors.

The thermal fluid flow problem is solved using the lattice Boltzmann method, which offers scalable performance on multicore clusters, which is necessary to obtain optimized designs within a reasonable time frame.
Supervisor: Ole Sigmund

SUNA YAN (guest, DTU Mechanical Engineering, 15 minutes)
Topology optimization of heat conduction structures using layered materials
The topology optimization of heat conduction structures in steady-state is analytically studied by using layered materials. The optimization problem is divided into two sub-problems: the inner one solves the optimal microscopic layers for a fixed bulk density and temperature field; the outer one solves the optimal material density distribution under given thermal loads and boundary conditions. The effective thermal conductivities of layered materials are computed by the homogenization approach. The optimal directions of layered materials are computed, which is in fact the direction of temperature gradient. The coincidence between the direction of heat flux and temperature gradient is proved when the layered materials are at the optimal directions. Through reformulating the energy function, a series of reduced forms of the inner problem are developed. The efficiency of rank-1 material for steady-state heat conduction problems is proved. In two pseudo-2D heat conduction cases, the optimal material density distributions are computed analytically subjected to the limit of a low fraction of material available. The density of material is proportional to the amount of energy that it carries. The analytical optimal distributions of rank-1 material for these two cases are then obtained. The work may help us learn more about topology optimization of heat conduction structures and have implications for checking the effectiveness of topology optimization methods.
Supervisor: Ole Sigmund

10:45 – 11:15 Coffee break

4 – INVITED PRESENTATION & OPTIMIZATION II
(Chairman: Niels Leergaard Pedersen, DTU Mechanical Engineering)

11:15 – 12:00 LARS VABBERSGAARD ANDERSEN (AAU Civil, 45 minutes)

Modelling Ground Vibration and Dynamic Soil–Structure Interaction

Environmental vibrations from traffic and construction work are major sources of annoyance in built-up areas. Assessment of such vibrations should therefore be included in feasibility studies and in all phases of construction design. Further, possibilities of mitigating environmental vibrations should be considered. This limits the possibility of relying on measurement, thus necessitating development and use of computational models for effective prediction of ground vibration levels and dynamic soil–structure interaction (SSI). Moreover, SSI plays an important part in the dynamic response of structures such as wind turbines to transient or cyclic loads from wind or waves. The presentation provides a brief overview of computational methods that can be used to analyse wave propagation in soil and dynamic SSI. The methods are compared regarding their respective advantages and disadvantages, including limitations and computational efficiency, and considerations regarding the modelling of soil as an unbounded medium are discussed. A couple of numerical examples are given for selected methods. The first example concerns a coupled boundary-element/finite-element model employed to analyse dynamic SSI for buildings subjected to ground vibration from an external source. The second example concerns different models utilized for assessment of the insertion loss achieved by placing an array of wave impedance blocks (WIBs) in a layered ground.

12:00 – 13:00 Lunch

Programme for Tuesday afternoon, March 14th, 2017

5 – FATIGUE & FRACTURE I
(Chairman: Henrik Myhre Jensen, AU, Department of Engineering)

13:00 - 14:30 LARS PILGAARD MIKKELSEN (DTU Wind Energy, 20 minutes)
Revealing fatigue damage evolution in unidirectional composites for wind turbine blades using x-ray computed tomograghy
Understanding fatigue damage evolution in the load carrying laminates of wind turbine blade play an important role designing longer and lighter turbine blades. Turbine blades which will make it possible to increase the size of wind turbines or to upgrade existing turbines for lower wind classes'. Thereby, it will be possible to lower the cost of energy for wind energy based electricity. In the presented work, a lab-source x-ray computed tomography equipment (Zeiss Xradia 520 Versa) has been used in connection with ex-situ fatigue testing of uni-directional composites in order to identify fibre failure during the fatigue loading. The load carrying laminates in wind turbine blades is typically based on a number of non-crimp fabrics in where the load carrying fibres are oriented in the axial direction of the blades. In order to ease the handling of the fabric during the dry fabric layup and to ensure a good alignment of the final laminates, approximately 10% of the fibres are oriented in secondary directions as so-called backing bundles and stitched to the uni-directionally oriented bundles. Due to the coarse structure of the non-crimp fabric, test samples with a larger cross-section (compared to other comparable x-ray studies) have been used in order to ensure a representative test volume during the ex-situ fatigue testing. Using the ability of the x-ray computed tomography to zoom into regions of interest, non-destructive, the fatigue damage evolution in a repeating ex-situ fatigue loaded test sample has be explored. Thereby, the fatigue failure mechanism has been uncovered showing fibre breakage regions growing from cross-over regions of the backing bundles. Based on those observations, more realistic micromechanical based fatigue damage models as well as suggestions on bundle arrangement improving the fatigue resistance of non-crimp fabric used in the wind turbine industry can be made.

EMILIO MARTINEZ-PAÑEDA (DTU Mechanical Engineering, 20 minutes)
Predictive modellingo of environmentally assisted cracking – a micromechanics conquest
The use of high-performance materials in energy infrastructure is firmly challenged by the detrimental effect of hydrogen - the ductility and toughness of structural alloys are dramatically reduced in corrosive environments. With current engineering approaches being mainly empirical and highly conservative, there is a strong need to understand the mechanisms of such hydrogen-induced degradation and to develop models able to predict the initiation and subsequent propagation of cracks as a function of material, environmental and loading variables.
However, hydrogen assisted cracking is a very complex mechanical-chemical problem that depends sensitively on mechanisms that pertain to the micro and atomic scales. The speaker and his collaborators have been actively engaged in the development of enriched continuumlike models that aim to incorporate the mechanisms governing hydrogen-assisted cracking. To this end, efforts have been devoted to investigate crack tip fields by means of strain gradient

plasticity (SGP) models, as classical continuum theories are unable to adequately characterize behavior at the small scales involved in crack tip deformation [1,2]. Grounded on the physical notion of geometrically necessary dislocations (GNDs), SGP formulations have proven to quantitatively capture the hardening effects associated with large gradients in plastic strain. Finite element results reveal that GNDs close to the crack tip promote local strain hardening and lead to a much higher stress level as compared with conventional plasticity.

Gradient-enhanced predictions proved to be particularly relevant in hydrogen embrittlement models due to the essential role that the hydrostatic stress has on both interface decohesion and hydrogen diffusion. Encouraging agreement with experimental data has been obtained by incorporating the influence of GNDs in the modeling of hydrogen transport [3] and environmentally assisted cracking [5]. The promising results achieved have attracted the interest of industrial partners and technical standards organizations, ending with a scientific/engineering handshake a journey that began from fundamental micromechanics.

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CHRISTIAN LOTZ FELTER (DTU Mechanical Engineering, 20 minutes)

Fracture in Plate Tearing

Many constructions of the world today is made from structural elements known as plates. Examples are cans (small scale) or ships (large scale). In order to predict the failure of such components the finite element method is often used with a special kind of modelling called cohesive zone elements. This method relies on measurement of the energy expended in advancing the crack in a test apparatus. It was during such experiments that a special crack propagation mode was observed -- the so-called crack tip flipping.

The aim of the present work is to model crack propagation in plate tearing, which displays the mentioned crack tip flipping from roughly +45 degree to -45 degree in a periodic manner along the crack growth direction. The Gurson-Tvergaard-Neddleman material model with solid 3D elements is employed to model the ductile growth of micro-voids in the material and localization of damage into shear-bands. An element deletion technique is used to erode elements away thereby allowing the crack to propagate in the finite element mesh. A parallel explicit code is written and run on the computer clusters at DTU Lyngby and Risoe Campuses.

The talk will high-light the components and workings of the Gurson model, and recent result are shown.

LASSE TIDEMANN (DTU Mechanical Engineering, 15 minutes)

Beam Element with Cyclic Plasticity Effects

Design of offshore structures is dominated by the actual behaviour of the structure even for ultimate limit states. In ultimate limit states large wave loads may lead to cyclic deformation in the structure, where the behaviour is governed by a combination of beam-column buckling and plasticity in both local beam members and tubular joints. In the case of cyclic plastic deformation it may be relevant to consider degradation effects at element as well as global scale.

A simple, highly accurate cyclic plasticity model with external and internal variables has been developed, based on a first order homogeneous kinematic hardening yield surface and a plastic flow potential with an additive term dependent on the internal hardening variables. The format of the plastic flow potential is carefully chosen to ensure a clear link between model parameters and characteristic stress levels and stiffness. Cyclic degradation is accounted for by evolution of the model parameters, consistently introduced in the constitutive relations by an extra set of internal variables.

The cyclic plasticity model is formulated in terms of generalized stresses and by the introduction of a generic, flexible yield surface format it is usable in both continuum and beam element formulations. Comparisons with experimental data on material as well as structural scale including cyclic degradation effects illustrate the accuracy and versatility of the cyclic plasticity model, with minimal effort model parameters are estimated to accurately represent the characteristic stress levels and shape of hysteresis loops of experimental data even for large structures.

Supervisor: Steen Krenk

JEPPE BJØRN JØRGENSEN (DTU WIND ENERGY, 15 minutes)

Crack deflection at interfaces

Crack deflection at interfaces is studied experimentally using a four-point single-edge-notch-bend (SENB) specimen and digital image correlation (DIC). It is important that the crack grows stable hence the crack deflection process can be captured on images during the test. Analytical models, for the four-point SENB specimen, to determine the stress intensity factor are available in the literature, e.g. Tada et al. 2000, provided the loads are applied as concentrated forces. However, the four-point SENB specimen is tested in the lab using applied displacements since stable crack growth are desired.

An analytic model of the four-point SENB specimen with applied displacements is derived using the compliance method. The derived model is demonstrated on the pure bending specimen and the four-point SENB specimen. A 2D plane strain FE model of the four-point SENB specimen is used to test the analytical derivation. The numerical and analytical models show that the start-crack-length must be relatively long for the crack to propagate in a stable manner. Thus, the energy release rate decreases with crack length if the start-crack-length is made sufficiently long.

Four-point SENB specimens, cast of pure glue, are manufactured and tested in the lab. The tests confirmed that the crack grows stable if the start-crack-length is made long and unstable if it is made short. Finally, four-point SENB specimens with glue cast onto a laminate is tested to study crack deflection at interfaces. The main crack grows stable until a secondary crack initiates at the glue-laminate interface resulting in abrupt crack growth of the main crack to the interface. This cracking mechanism is also confirmed numerically.

Supervisor: Bent F. Sørensen

14:35 - 18:00 Social Event

19:00 - Banquet

Programme for Wednesday morning, March 15th, 2017

07:00 - 09:00 Breakfast

6 – DYNAMICS & OPTIMIZATION II
(Chairman: Sine L. Wiggers, SDU, ITI)

09:00 - 10:20 POUL G. HJORTH (DTU Compute, 20 minutes)

Pedestrian Dynamics from Social Force Models

Numerical simulation of pedestrians moving as mass points under the action of social forces and reacting to forces from obstacles provides a way to study crowd phenomenae. Many such social force models with inflexible parameters suffer from limited validity when they are applied to various scenarios. We give examples of this, and demonstrate pathological cases of unrealistic stationary points arising in models with potential forces. To overcome this problem we propose, and mathematically formalize, a novel hybrid modeling approach including dissipation via a friction term, where pedestrian behavior is situation-dependent, i.e., switches between equations of motion according to the relative location to an obstacle. A number of scenarios are studied to illustrate the advantages of such a hybrid model approach.

KASPER RINGGAARD (AU, Department of Engineering, 15 minutes)

Development of reconfigurable parallel kinematic machining cell for large wind turbine components

Standard machining centers are built rigid to guarantee accuracy, and the reachable workspace is small compared to the machine size. The same applies for machining centers for large wind turbine parts where the workspace covers several cubic meters. Purchasing such large machines is a large investment, which eventually makes wind turbines more expensive.

One way of lowering the investment is to think the other way around; Build a small and reconfigurable machining cell and relocate it to reach the entire workpiece. This Ph.D. research is part of an Innovation Fund financed collaborative project working towards making a small and reconfigurable machining cell feasible and economically viable for serial production of wind turbine components.

Specifically this research regards development of a reconfigurable parallel kinematic machining cell. The aim is prediction of deflections and vibrational response of the machining system using elastic multibody dynamic simulations. This presentation covers an introduction to the basic challenges encountered in the development of such machinery for a wind turbine hub case. The importance of workpiece compliance and dynamic response is assessed using a Finite Element Model of the hub, and results are presented. Furthermore, the initial steps and findings regarding development of a parallel kinematic machining center is presented and discussed.

Supervisor: Ole Balling

CHRISTIAN LUNDGAARD (DTU Mechanical Engineering, 15 minutes)

Topology optimization of thermoelectric energy conversion

Thermoelectric energy (TE) conversion is a two-way process which may refer to the conversion of thermal temperature differences into electric energy or vice versa. This study demonstrates the application of the density-based topology optimization (TO) approach for TE off-diagonal figure-of-merit

optimization problems. The TE figure-of-merit is a key parameter in improving the TE energy conversion performance. TE off-diagonal problems are characterized by an imposed vertical temperature difference which aim on generating a horizontal electric potential difference. Materials with high off-diagonal TE figure-of-merits have low horizontal thermal conductivities, high vertical electric conductivities and high off-diagonal Seebeck coefficients.
To set up the optimization framework, the generalized Fourier's and Ohm’s differential equations are discretized using the finite element (FE) method, and the off-diagonal TE figure-of-merit is optimized by determining the spatial distribution of two arbitrarily chosen TE materials. The physical modeling is limited to two dimensions, steady state and temperature independent materials. The optimization sensitivities are computed with the discrete adjoint method and the optimization problem is solved using the Method of Moving Asymptotes (MMA). The optimization problem is set up in the well known robust formulation, and it is demonstrated that the robust formulation may ensure binary optimized designs.
The study demonstrates that density-based topology optimization is a viable approach for optimizing the off-diagonal TE figure-of-merit, as significant design improvements are obtained by the presented framework compared to designs obtained with other optimization approaches in the literature.
Supervisor: Ole Sigmund

FEDERICO FERRARI (guest, DTU Mechanical Engineering, 15 minutes)
Alternative formulation of some eigenvalue problems in topology optimization
We present an alternative to the standard approach for fundamental eigenvalue maximization in the context of topology optimization for dynamics. The motivation is to avoid or at least attenuate the many inherent shortcomings of the classical formulation and to reduce the computational cost for large problems. The idea underlying the method is to generate a sequence of frequency response minimization problems for a suitable set of external loads and to minimize the associate dynamic compliance. If the frequency and the shape of the load are selected so that all the eigenmodes associated with the target eigenvalue are excited during the optimization, the method performs very effectively, giving a design equivalent to the one from standard approach.
A reasonably accurate estimate of these parameters can be obtained with low computational expense by means of a multilevel discretization and the solution of an eigenvalue problem only on the coarsest level. The performance of the overall method is tested on some examples, showing its simplicity and computational convenience compared to the standard approach.
Supervisor: Ole Sigmund

JONAS SJØLUND (AAU, MAKE, 15 minutes)
Continuous plygroup thickness optimization of offshore wind turbine blades
The length of offshore wind turbine blades keeps increasing, and it is expected that 100 m blades will be reality soon. In general wind turbine blades are built of stacked layers of thin fiber mats. Long offshore wind turbine blade can require hundreds of layers locally to satisfy the structural requirements. Due to the complexity of the problem, optimization methods are often used to determine the locally required number of plies. A traditional optimization approach may choose to treat the fiber orientation and material of each layer as design variables.

However in reality, wind turbine blades typically have relatively large groups of layers with identical fiber orientation and material. This suggests that a parameterzation into groups of plies (plygroups) may reduce the optimization problem to a more reasonable size while still providing good results. A demonstration of this parameterization will be performed on a 73 m offshore wind turbine blade, utilizing finite element analysis and gradient based optimization methods.
Supervisor: Erik Lund

10:20 - 10:50 Coffee break

7 – MATERIALS, PROCESS MODELLING, FATIGUE & FRACTURE II
(Chairman: Kim Lau Nielsen, DTU Mechanical Engineering)

10:50 – 12:05 KRISTIAN JØRGENSEN JUUL (DTU Mechanical Engineering, 15 minutes)

Numerical Framework for Self-Similar Problems: Indentation in Single Crystals

A numerical framework specialized for self-similar history dependent problems is developed. This kind of self-similarity is encountered in a number of different problems such as stationary cracks, void growth, indentation etc. Such problems are currently handled by traditional Lagrangian procedures that may be associated with several numerical difficulties (sufficient discretization, moving contact points, etc.). Here, self-similarity is exploited to construct the numerical framework that offers a simple and efficient method to handle self-similar problems. The procedure allows for focusing the mesh only in regions of interest giving highly detailed results in compared to traditional frameworks. The technique is here applied to wedge indentation in elastic-viscoplastic single crystals (the framework may be applied to a wide range of material models).

The three most common metal structures are investigated, namely the FCC, BCC, and HCP crystal structures, where the slip rate fields and stress fields will be compared to analytical predictions by Saito and Kysar (2011) and traditional numerical simulations by Saito et al. (2012) when possible. Saito and Kysar (2011) proved analytically the existence of discontinuities in the slip rate field. The numerical simulations reveal a striking match to the analytical prediction showing the expected discontinuities in the slip rate field. In addition, the current results provide much more detailed views of the field quantities than previously obtained.

Supervisor: Kim Lau Nielsen

MARCO MADURO (DTU Wind Energy, 15 minutes)

Effect of different curing schemes on the formation of residual stresses during the production of fiber reinforced composites and evaluation of their final mechanical properties

In this work, the effect of different curing schemes of a polyester resin on the formation of residual stresses during the production of a fiber composite material was evaluated. Characterization of the thermoset resin was done by differential scanning calorimetry in order to build a model which predicts the degree of cure (DoC) considering temperature and time as input variables. The glass transition temperature (Tg) was modeled as dependent of the DoC. The induced strains caused by the chemical shrinkage due to crosslinking reaction and thermal contraction during cooling were measured by means of Optical Fiber Bragg Gratings, using a simple set up consisting of unconstrained neat polyester resin samples. The curing schemes were designed considering long curing times at low temperatures, which are typical of a wind blade manufacturing process, short curing times at high temperatures (above the ultimate glass transition temperature (Tg)) and multi-steps curing schemes with intermediate temperature holds. The influence of the curing schemes on the final mechanical properties of the composite material was evaluated. Test specimens of laminates consisting of UD and biaxial fibers were produced and tested under static and dynamic loads.

Supervisor: Bo Madsen

ULRICH MORTENSEN (DTU Wind Energy, 15 minutes)

Fatigue damage caused by bending loads in uni-directional non-crimp fibre reinforced polymers

Bending fatigue behavior of basalt fibre reinforced epoxy is investigated by observations of micro-cracks forming in the material. Standard Rectangular specimens of the Basalt fibre/epoxy material with finely polished sides are cyclically loaded using a 4-point bending fixture. Micrograph that shows crack formation and propagation is documented through intermittent microscopy of the polished sides of the specimen. The micrographs obtained also serve as evidence of what damage mechanisms are involved in the macroscopic stiffness degradation of the material. Results are in line with previous observations made by other researchers (Zangenberg et. al, Munk et. al) showing that fibre breaks in load carrying fibre bundles occur frequently in the vicinity of backing fibre bundles, and rarely in areas away from backing fibre bundles. The hypothesis is that the main mechanism causing fibre breaks are cracking in transverse (backing) bundles initiated in the early stages of the lifetime of the material, which then leads to de-bonding of fibres in load carrying bundles and then finally to fibre breaks. The observed stiffness degradation seen in the corresponding S-N curves are related to the observed damage mechanisms. In the future there will be an effort to input the damage observed in the micrographs into finite element simulation in order to validate that the stiffness degradation of the material may be caused by the observed damage mechanisms.

Supervisor: Lars P. Mikkelsen

SEYED AYDIN RAEIS HOSSEINY (AAU MAKE, 15 minutes)

Prediction of fatigue damage in tapered laminates

Effective implementation of ply-drops configurations substantially improve the damage tolerant design of flexible and aero-elastic wind turbine blades. Terminating a number of layers for an optimized blade design creates local bending effects. Inter-laminar stress states in tapered areas give rise to delamination and premature structural failure. Precise calculation of the stress levels for embedded ply-drops is required to predict failure initiation within acceptable limits.

Multi-axial stress states in orthotropic laminates subjected to diverse loading mechanisms nucleate microscopic cracks. By increasing the cracks density, damage occurs when residual material properties reduce to a critical level. Residual strength and stiffness of simple laminates are assigned in a set of fatigue failure criteria to assess the remaining life of the components by increasing number of loading cycles. The mode and position of damage initiation in ply-drops area is predicted accordingly.

Supervisor: Johnny Jakobsen

MERTASH MANOUCHEHR (DTU Mechanical Engineering, 15 minutes)

Effect of high voltage electric field on the fatigue life of GFRP laminates

The traditional design of high voltage power pylon masts has been used for decades without major changes. These structures usually made of steel or aluminium have raised public resistance due to visual noise they impose in the field.

A new concept developed by an architecture company, Bystrup, has aimed in taking advantage of composite structures for different reasons. The glass fiber reinforced polymer (GFRP) materials are considered non-conductive which results in smaller dimension of the pylon. Different part can be integrated in to one piece which reduces the manufacturing time. These structures are light weight which makes it possible to use alternative form of transport such as helicopters to carry them on sites where ever the accessibility is an issue and speed up the installation process.

However even though GFRP is considered non-conductive, when they are exposed to high voltage electric field it is expected to experience the aging faster compared to pure mechanical loading as the presence of voids and other impurities raises the possibility of partial discharges which degrade the material in long run.

In this project this issue has been addressed and different experimental test setup and configuration have been designed to investigate the effect of high voltage electric field on GFRP materials. What is presented here is the first phase of this project which tries to find out if there is any considerable degradation in the material and what mechanisms would be involved in that. The results are the outcome of combined mechanical-electrical loading of specimens. The effects of different parameters such as material layup, void content and resin system have been investigated in these experiments.

Supervisor: Christian Berggreen

12:05 – 13:30 Lunch

14:00 Departure from the hotel